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Article

Agent-Based Models as "Interested Amateurs"

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Abstract: This paper proposes the use of agent-based models (ABMs) as "interested amateurs" in policy making, and uses the example of the SWAP model of soil and water conservation adoption to demonstrate the potential of this approach. Daniel Dennett suggests experts often talk past or misunderstand each other, seek to avoid offending each other or appearing ill-informed and generally err on the side of under-explaining a topic. Dennett suggests that these issues can be overcome by including "interested amateurs" in discussions between experts. In the context of land use policy debates, and policy making more generally, this paper suggests that ABMs have particular characteristics that make them excellent potential "interested amateurs" in discussions between our experts: policy stakeholders. This is demonstrated using the SWAP (Soil and Water Conservation Adoption) model, which was used with policy stakeholders in Ethiopia. The model was successful in focussing discussion, inviting criticism, dealing with sensitive topics and drawing out understanding between stakeholders. However, policy stakeholders were still hesitant about using such a tool. This paper reflects on these findings and attempts to plot a way forward for the use of ABMs as "interested amateurs" and, in the process, make clear the differences in approach to other participatory modelling efforts.

Keywords: agent-based models; participatory modelling; policy making; soil and water conservation; interested amateurs

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1. Introduction

Policy making is a complex process [1–3] involving many actors. This is especially true of land use policy in which many different stakeholders interact. In any policy domain, individual actors often have

little control over the process [4]. Most, if not all, of these actors are experts in their policy area; their (and their organisation's) combination of experience in policy making and the domain area mean that they often have detailed knowledge and strong opinions on what policies may and should be pursued and which actors should be included in the process. Despite this, we know policy making and policies themselves are not always successful. Why might this be?

There are, of course, many reasons for this, but one may be that these "policy experts" are not working together as effectively as may be possible or necessary. New ideas may be consistently ignored or out-of-date assumptions may go unscrutinised. Why might experts be unable to interact successfully? Dennett [5] suggests that when experts on a subject debate or discuss that subject, they assume the expertise of others and do not discuss basic concepts. The result is that they often "talk past" each other and fail to identify differences in assumptions and key understandings of the topic or system under discussion. This can also be the result of experts not wanting to offend one another or appearing ill-informed by asking for explanations of basic positions and assumptions. In either case, the experts end up erring on the side of under-explaining or discussing the topic at hand.

Dennett's proposed solution to this general problem is to use lay audiences, or curious non-experts (here called "interested amateurs"), to force the discussion to be focussed on assumptions and to err on the side of over-explaining issues under discussion. For Dennett, an academic philosopher, this means bringing undergraduate students into discussions and debates and asking them to query anything they find unclear.

This paper suggests that it is agent-based models (ABMs), via their overall design, agent rules, assumptions and results, that can play the role of "interested amateur" in policy making and, thus, potentially aid the interaction of policy experts. Moreover, it is suggested that they have an unusual combination of characteristics, such as specificity, intuitive appeal and representation of causation, that makes them excellent candidates for this role. Their specificity encourages detail in discussions, whilst their intuitive appeal keeps ideas tractable and the bigger picture within reach. As models are not people expressing opinions, but artefacts without emotions, it is suggested that participants in discussions are more likely to make strong critiques of a model than an expert or a person playing the role of an "interested amateur". It is this critique that brings otherwise hidden beliefs and assumptions into the open. These assertions will be explored using the example of the SWAP (Soil and Water Conservation Adoption) model of soil and water conservation (SWC) adoption amongst small-scale farmers in developing countries. The SWAP model was used with SWC policy stakeholders in Ethiopia (a policy area with well-documented interaction problems [6,7]). A workshop with policy stakeholders was held and a qualitative analysis used to understand if and how an ABM could act as an "interested amateur".

There is already a considerable literature on the use of models, and specifically ABMs, in participatory policy making contexts. This increasingly diverse field [8] is excellently overviewed by Voinov and Bousquet [9] and Matthews *et al.* [10]. Most relevant and notable within this literature is the companion modelling (or ComMod) approach developed at the French Agricultural Research Centre for International Development (see [11,12] for overviews of the approach). The approach's "charter" [13] outlines the principles upon which it is based. The approach places the utmost importance on interaction between modellers and stakeholders from the beginning of a project, with many iterations. The focus is placed on learning between researchers and stakeholders, and between stakeholders

themselves, and using the process to come to decisions and/or build decision-making capacity. There are numerous examples of the application of ComMod, including water management in Bhutan [14], natural resource management [15] and forest management [16] in the Philippines and fishery management in Thailand [17].

ComMod has been very popular and successful in a range of contexts. However, there are some situations in which it may not be the best approach to take. Models created using the ComMod methodology are co-constructed by a group of stakeholders who, as a result, all have ownership of a model. This means that the model is an "insider"; it is part of their work and likely reflects their view of the world. In this sense, a ComMod model cannot play the role of an "interested amateur", as it is not an "outsider". This means that stakeholders are less likely to make strong criticisms of the model or include elements in its design that they do not see as relevant, but that others, outside the ComMod process, may view as important. Furthermore, any model created by stakeholders is likely to reflect and reinforce their current thinking. A diverse group of stakeholders can share and influence each other's thinking, but it is unlikely ideas from outside these bounds will be included in the model. This lack of both "outsiderness" and an inclusion of critique and thinking from outside the stakeholder group are not typically considered as weaknesses of the ComMod approach, and in many circumstances with specific aims, they are not. It is not the intention here to suggest that they are problematic in all situations, but to suggest that it is worthwhile considering what value a model, that is an "outsider" and that contains thinking from outside the current policy practice, may have in participatory contexts. This underpins the aim of this paper to explore the potential of ABMs to be used in participatory contexts in a different way: as "interested amateurs".

The rest of this paper is structured as follows. In Section 2, the SWAP model and the context it was used in are presented alongside findings from a workshop with stakeholders in Ethiopia. This serves as a demonstration of the use of an ABM as an "interested amateur". In Section 3, a more general discussion is put forward on when and how we might use ABMs as "interested amateurs". Finally, Section 4 concludes.

2. The SWAP Model

This section presents both the SWAP model itself and the approach and findings of a stakeholder workshop used to explore its use as an "interested amateur".

2.1. Model Description

A description of the model is given here which is sufficient for the purpose of this article; however, in the interest of space, this is not comprehensive. A complete description, including an ODD (Overview, Design Concepts, Details) protocol [18,19], is given by Johnson [4], and the model can be downloaded with the full code at http://modelingcommons.org/browse/one_model/4117. The model was developed in the open source environment NetLogo [20]. Using NetLogo enabled the model to be built in an environment with a well-established community and in a relatively naturalistic programming language. The SWAP model is a relatively simple ABM. There are two types of agents: farmer agents and extension agents. Farmer agents make a decision between using two generic farming methods: non-SWC methods

or SWC methods. This decision and the design of the agent rules more broadly are based on a framework developed and tested in the literature by DeGraaff *et al.* [21]. This framework breaks up the decision into multiple steps and attaches different factors to these. It also allows for the intensity of adoption, rather than a simple dichotomous choice. First, farmers must accept the need for SWC, then they must decide on how much of their farm to adopt SWC, and finally, once adopted, they must continue to decide to maintain adoption (see Figure 1). The agents' basic decision is intended to be as close an implementation of the DeGraaff framework as possible.

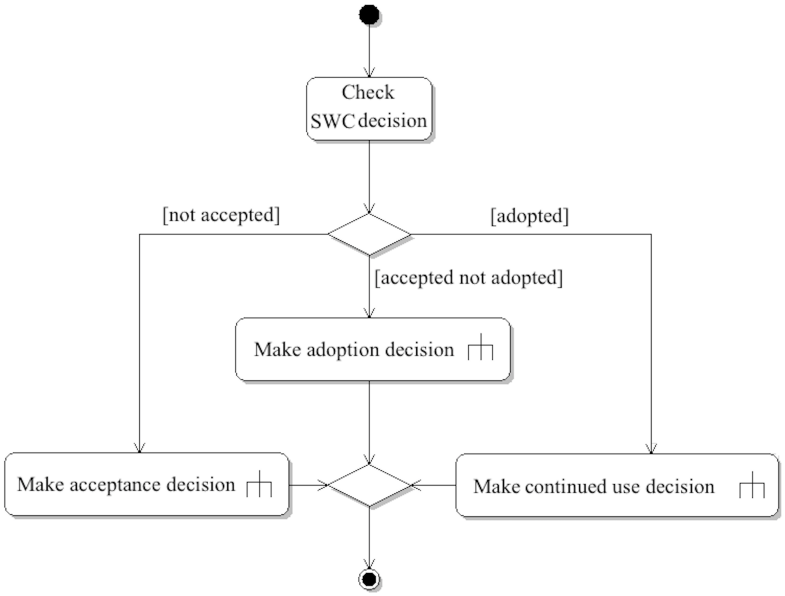

Figure 1. Farmer agents' basic decisions.

The acceptance decision is the most complex, based on the DeGraaff *et al.* framework [21], and requires the following eight steps given in pseudo-code:

```
(1) Run symptoms recognised?
   if ( farm soil quality is low )
   and ( decision maker works on farm )
   and ( farmer knows the land well )
   then [ recognise symptoms ]

(2) Run effects recognised?
   if ( farmer not too old )
   and ( farmer knows the land well )
   and ( farmer is well educated )
   and ( farmer has extension contact )
   and ( farmer has low cultural inertia )
   then [ recognise effects ]

(3) Run degradation taken seriously?
   if ( farmer has extension contact )
   and ( farmer owns the land )
```

```
   then [ take degradation seriously ]

(4) Run aware of SWC methods?
   if ( farmer has knowledge of methods )
   and ( farmer has extension contact )
   then [ be aware of methods ]

(5) Run able to undertake SWC?
   if ( farmer can hire labour )
   and ( farmer not too old )
   and ( farmer has extension contact )
   and ( farmer can access credit )
   and ( farmer owns the land )
   then [ able to undertake SWC ]

(6) Run willing to undertake SWC?
   if ( discount rate is low )
   and ( farmer has low cultural inertia )
   and ( farmer sympathetic to gov/NGOs )
   and ( farmer has a family successor )
   and ( farmer is not too old )
   and ( decision maker works on farm )
   then [ willing to undertake SWC ]

(7) Run ready to undertake SWC?
   if ( not too risk averse )
   and ( farmer has enough savings )
   and ( farmer has enough income )
   then [ ready to undertake SWC ]

(8) Run accept SWC
   set acceptance score to
   [ accepted but not adopted ]
```

The various parameters required to implement this pseudo-code are either dichotomous (e.g., the decision maker works on the farm, the farmer has an extension contact, the farmer owns their land, the farmer can access credit or labour, the farmer has a successor), assigned a score between zero and one hundred (e.g., cultural inertia, knowledge of methods, sympathy to non-governmental organizations or government) or given an appropriate value (e.g., age is in years, years of education is in years, the discount rate, which denotes the rate at which farmers discount future costs and benefits against current costs and benefits, is given as a number between zero and one). These are then set using real-world data where available.

Each of the eight steps must be met for the farmer to proceed to the next stage of the decision. However, at each time step, there is a 10% chance that the agent will jump straight through the acceptance

decision without meeting its criteria and move onto the adoption decision; this represents an element of chance in the decisions. This figure was reached after the calibration and sensitivity analysis.

Once they have accepted the need for SWC, farmers must decide on the intensity of their adoption, *i.e.*, how much of their farm they wish to adopt. The amount of land they adopt conservation on is determined by their level of savings (intended to represent an abstract form of capital, savings must meet a minimum threshold), their contact with extension workers (a contact is required for any adoption) and their risk aversion score (less risk-averse agents will adopt at a higher level).

Finally, if they have already adopted SWC measures, farmers must decide whether to increase or decrease adoption or indeed stop using SWC. If their "income" is higher than their "consumption requirement", they will increase adoption by 20%. If their "income" is lower than their "consumption requirement", they will reduce their adoption by 20%. If adoption falls at a very low level, they will simply stop using SWC. The presence of adoption will increase soil quality, which, in turn, will increase an agents "income" parameter. "Consumption requirement" in the model is a constant (per individual) multiplied by the number of people in a farmer's household, and "income" is a function of the soil quality and farmer knowledge.

Farmers also interact in the model, either: in farmer peer-groups, such as church or community groups, through influential individuals, such as community leaders or government chosen "model" farmers, or through extension agents (see Figure 2).

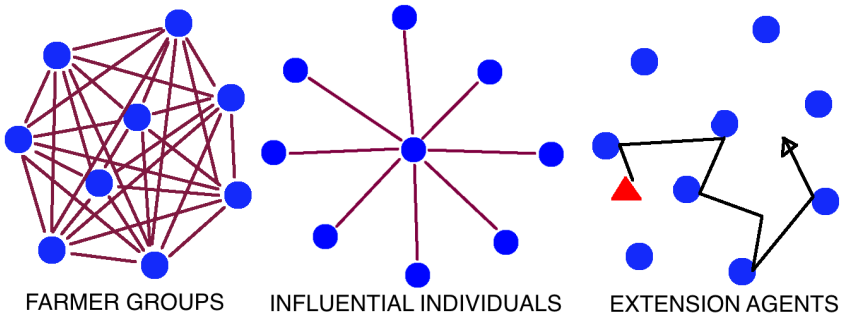

Figure 2. Farmer interactions.

In farmer groups, farmers become more similar, all influencing each other equally as peers. Via influential individuals, those with higher "influence scores" make those near them more like themselves. Extension agents (representing development agents, as described in the next section) move around the model space increasing the chance of farmers adopting SWC when they are nearby, as extension contact is key to several of the decision stages. These interaction types are not described in the DeGraaff *et al.* framework, but are derived from a wider reading of the SWC literature. They are included, as it was felt it was important to represent the social interaction of farmers, as well as their individual decision making.

During each time step, the agents take it, in turn, to make decisions in a randomised order. In one time step, an agent can start a decision and carry it out, but only one stage at a time; they cannot cycle through all of the decision stages at once (*i.e.*, an agent can decide that they recognise the existence of degradation, but cannot then also suddenly be aware of methods to combat it; or an agent can decide that they do accept the need for SWC, but then cannot also decide how much to adopt). This separation of the decision process over time reflects the idea that farmers do not go from not being aware of or

considering SWC to suddenly adopting. The time step is intended to represent a period of around one to three months. This is a reasonable period for which to assume agents would make these decisions in the real world (*i.e.*, a farmer does not consider whether to change practices every day or week).

The spatial environment represents a non-specific area of land made up of many "patches". Each patch of land represents a field, with the collection of patches closest to each farmer agent being their farm. The environment is modelled in this way so that farmers can decide on the intensity of adoption on their farm, rather than making a simple dichotomous choice. Each patch has a parameter reflecting its soil quality, with a score out of one hundred. This is used to allow the feedback between decisions and soil quality and *vice versa*.

Though not the focus here, and not presented at the workshop, the model has been calibrated and validated against three case studies using real-world data and a pattern-oriented modelling approach [22–24]. A presentation of this process can be found in Johnson [4].

2.2. The Workshop

The workshop was held on 20 June 2013, at the International Livestock Research Institute (ILRI) Info-Centre in Addis Ababa, Ethiopia. In Ethiopia, as in much of Sub-Saharan Africa, land and soil degradation are increasingly problematic environmental, social and economic problems [25,26]. In the face of stagnating agricultural productivity, farmers have tended to expand production onto inappropriate and steep land, resulting in soil degradation and erosion [7]. Ethiopia's population now exceeds 80 million, with 75%–85% of the population making a livelihood in an agriculture industry characterised by low input-low output rainfed systems focussed on subsistence [7]. This has resulted in a strong perception that soil erosion poses a serious threat to Ethiopia's future despite widespread awareness amongst policy makers both in the country and externally. Policies in Ethiopia intended to increase farmers' adoption of SWC measures are understood to have been unsuccessful owing to:

> "*misguided policy, authoritarian and top-down approaches guided by targets and coercion to mobilise labour, blanket approaches across vastly different agro-ecological and socio-economic contexts, or inappropriate technologies*" [6] (p. 5).

This reflects Ethiopia's political past under the Derg and, more recently, slow progress in moving towards more participatory policy making [7]. Ludi *et al.* [6] also highlight the difficulty of the work of "development agents" that are intended to provide a bridge between government and farmers, stating that they are:

> "*caught between farmers and government, with the difficult task of reconciling top-down plans and quotas with local concerns and needs. They transmit information down to farmers but struggle to pass ideas and reflections back from farmers to higher levels*" (p. 19).

This second quote provides an excellent summary of the motivation for the use of the SWAP model as an "interested amateur" in this example. It is suggested that the model, via its overall design, agent rules, assumptions and results, can help to address this struggle in passing ideas and information up the policy hierarchy, between different "experts" on the system at hand. In a hierarchical and often sensitive policy landscape, the model can ease tensions by being the artefact that takes the criticism and critique

of stakeholders, but still allows for focused, detailed and tractable discussion on various levels of the system. The workshop aimed, using a qualitative approach, to explore how the model performed in this role and how participants viewed the potential for the model to be used as an "interested amateur".

2.2.1. Participants

Potential participants were identified based on their positions in the regional Bureaus of Agriculture (responsible for agricultural policy implementation, coordination and evaluation) and the non-governmental organisations (NGOs) working with them. This "mid-level" position was ideal for the workshop aims, as the participants had experience working with stakeholders both at the local and national levels and, so, were well positioned to comment and reflect on the potential for poor interaction amongst stakeholders "up" and "down" the policy process. Table 1 outlines the participants' positions and expertise.

Table 1. List of workshop participants. SWC, soil and water conservation.

No.	***Organisation***	***Expertise/Position***
1	ORDA	Project Design and Action Research Officer
2	BoA Amhara Region	Soil and Water Conservation Specialist
3	BoA Amhara Region	Livestock Expert in Watershed Study Case Team
4	BoA Amhara Region	Agronomist in Integrated Watershed Planning team
5	BoA Amhara Region	Livestock and Forage Development Advisor
6	GIZ-SLM Amhara Region	SWC Engineering Specialist
7	GIZ-SLM Oromia Region	Senior Cluster Advisor
8	BoA Oromia Region	Watershed Development Planning Expert
9	BoA Oromia Region	Agricultural Engineer for SWC

NB: ORDA = Organisation for Rehabilitation and Development in Amhara; NGO. BoA = Bureau of Agriculture. GIZ-SLM = Deutsche Gesellschaft fur Internationale Zusammenarbeit (Sustainable Land Management Project); a non-Ethiopian Government Programme.

The Amhara and Oromia regions were well represented, as they are the two most populated regions. The main omission was participants from Tigray, the Ethiopian region with arguably the most political influence and with a long history of soil degradation. This may because the distance from Tigray to Addis Ababa deterred potential participants. Though there was a majority of Bureau of Agriculture participants, there were also enough non-Ethiopian government programme and NGO participants, such that their voices would not be drowned out or ignored. It was the general characteristic of a mix of participants, rather than specific groups or types of participant, that was important for the aims of the workshop. A mixed group meant it was unlikely the participants would all have very similar views. Had the group been more homogeneous, it is unlikely that the approach would have had a fair chance of drawing out misunderstandings and differences of opinion, as they would be much less likely to exist.

It is possible that the findings from the workshop are biased by the characteristics of the group of participants that took part. The fact that they were willing to take part and travel quite far in some cases suggests that they were already interested in visiting ILRI, in the researchers' work and/or tools, like the SWAP model. Generally, it is fair to assume that they are more engaged with researchers and interested than a typical mid-level policy stakeholder. The final participant list was also not comprehensive in the sense that it covered all regions or types of organisation working on SWC. This means that it is difficult to attempt to generalise the findings beyond government and large NGO actors or to other regions. Despite these potential drawbacks, the findings of the workshop can still be used to demonstrate the potential of the "interested amateur" approach, make attempts at understanding how policy stakeholders view tools, such as the SWAP model, and how they might fit into their work.

All of the participants spoke English to a functional level, and most spoke well. There were very few occasions during which translation into Amharic was required. However, the participants did on occasion switch to talking in Amharic with each other. This was obviously more convenient and natural for them, but meant that the non-Amharic speaking organisers could not understand what they were saying. There did not appear any obvious reason for this change in language in terms of the content of the discussion (e.g., a sensitive or complex topic); rather, it appeared that the participants did this when they wanted to say something quickly or with more clarity, though it is impossible to be 100% certain. When this persisted for more than a few sentences, humour was used to attempt to return to English, though this was rarely necessary.

2.2.2. Workshop Structure

The workshop was split into four substantive sessions, in addition to an introduction and wrap-up. The sessions were in the format of an initial short (approximately ten minutes) presentation, an extended discussion in break-out groups of four to five participants and a final whole-group "report-back" on discussions. Participants were asked to make notes on their discussions using flip-charts. These were used to refer back to after the workshop and as prompts during the whole-group feedback sections. Though timing slots were detailed in the workshop materials given to participants, they were left intentionally flexible, and where possible, time was extended or shortened to accommodate the natural flow of discussion. Indeed, on the day, the timings were not stuck to closely.

Of the four sessions, two were generic in nature, relating to experiences of the policy process, and two were directly related to the SWAP model. The first of these introduced participants to the model and built a discussion on SWC using the model. The aim of this session was two-fold: first, to get a basic sense of the views of the participants on the model and, second, to demonstrate the use of the model as an "interested amateur". This was done by asking the participants to critique the model and explore their views, both when they agreed or differed. The framework and underlying assumptions were used as the main focus here, rather than the results or live "running" of the model. The second of the two sessions introduced the envisaged use of the SWAP model and built discussion on the participants' view of this. The aim was to understand whether the participants agreed that the SWAP model could be used as an "interested amateur", explore any other potential uses and understand what barriers there may be to its use.

2.2.3. Presenting the Model

If we are to suggest that ABMs have particular characteristics that make them good "interested amateurs", it is important to carefully consider how a model is presented to stakeholders. For this workshop, it was decided to present the SWAP model in two ways: first, to give an overview of the purpose, assumptions and results of the model in a short presentation, including videos of the model running "live". Figures 3 and 4 give a sense of what was presented in this section, showing a screenshot of the model interface and some of the results of the model when different interaction type scenarios are compared. Secondly, the framework of individual farmer decisions and interaction using handouts with diagrams (using Unified Modelling Language), pseudo-code and text (not dissimilar to those used in this paper) was presented. The most detailed attention was given to exploring the individual farmer decision making and interaction rules, rather than exploring model results or different analyses of outputs.

The participants were then given the task of critiquing the model in small groups. This meant that the participants received a focussed introduction to the model in a presentation and, then, a self-led critical exploration of the model using the handout materials. Giving the presentation first meant that the participants were able to get a sense of the overall purpose of the model, its components and results. Beyond this, they were also able to get a sense of what information on the model was being handed out and to what level of detail they could consider the model, but without having to actually go through all of the information themselves.

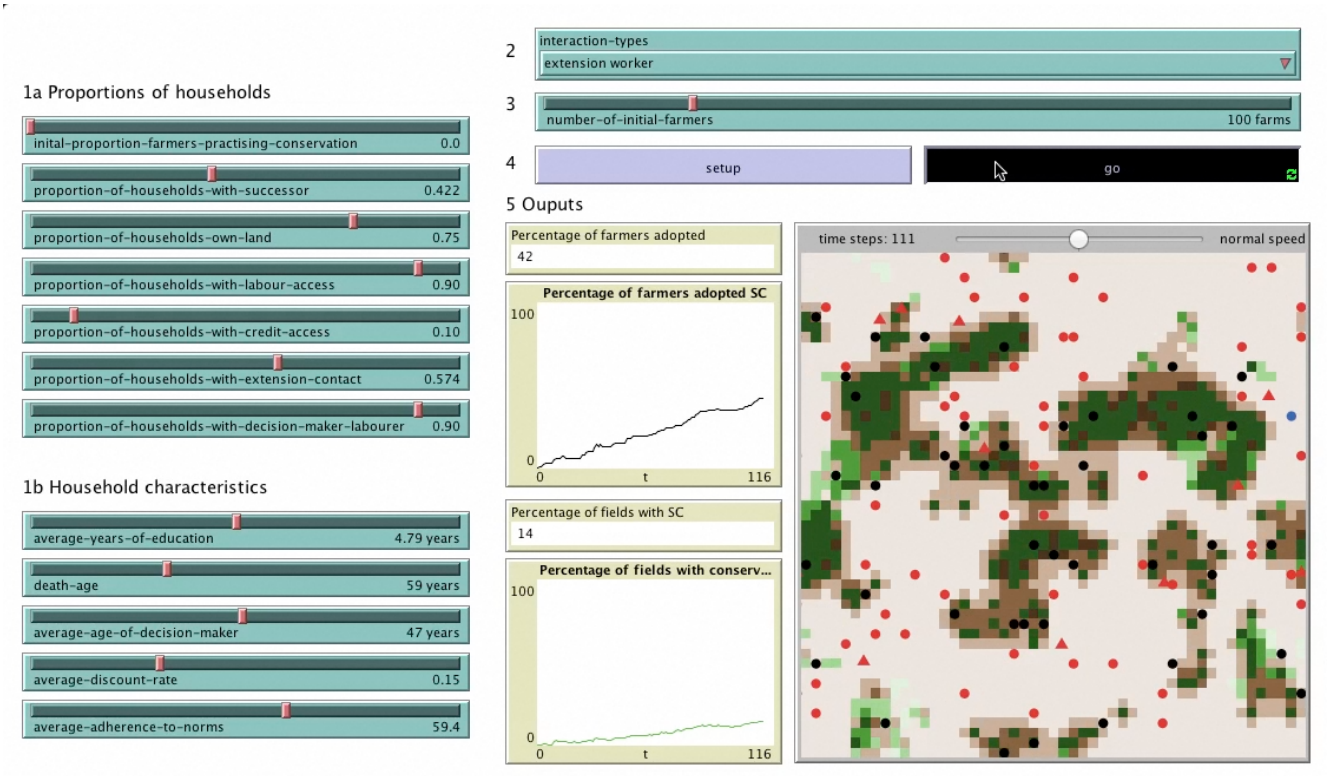

Figure 3. Screen shot of the model being run "live" for the participants.

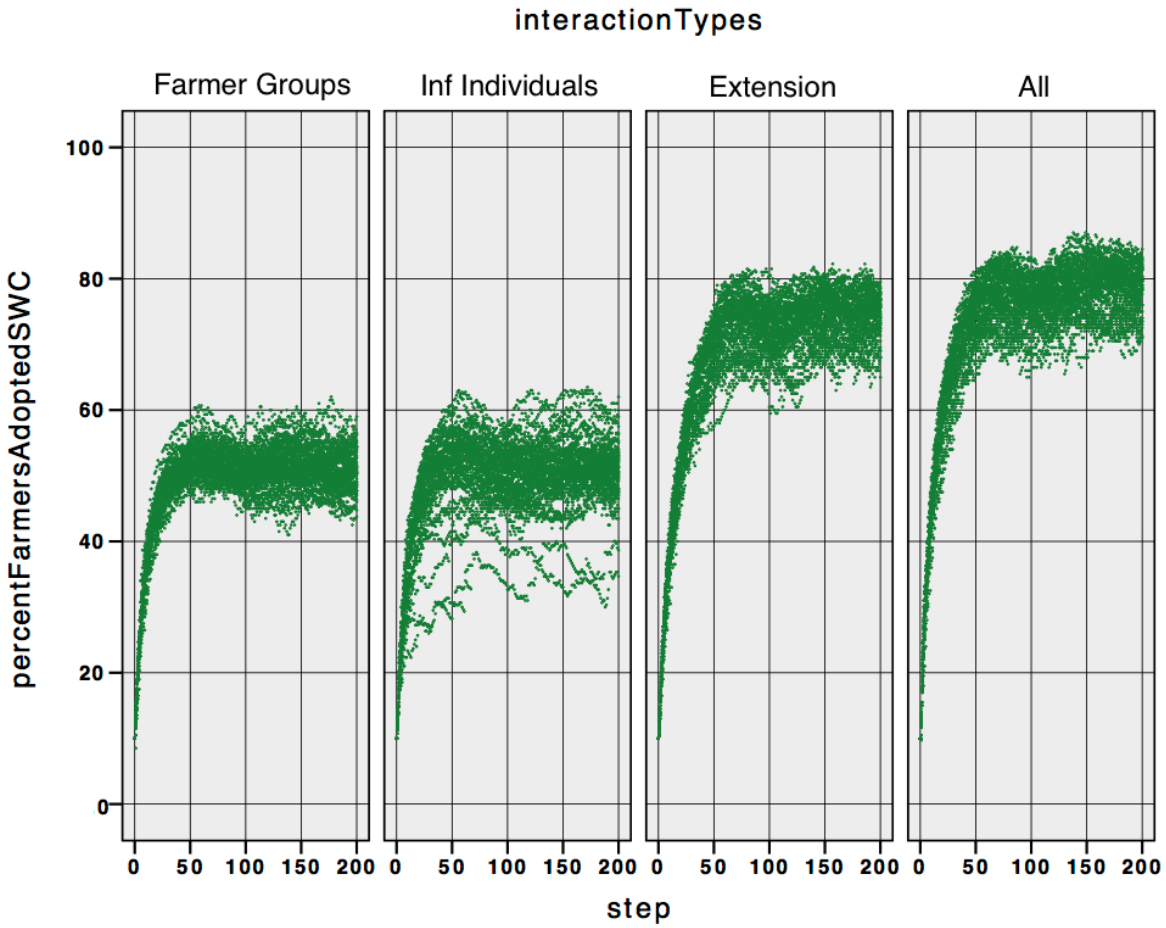

Figure 4. An example of model results shown to the participants: this graphs shows the percent of farmers adopting SWC under different interaction type scenarios for multiple runs of the model.

It was this premise of a quick overview, followed by a self-led task with depth available when required, that inspired the approach taken. It was during the break-out group discussions that the detail of the model really came to the fore. As the participants asked questions and made comments, the handouts were used to give the finer-level granular detail. Much use was made of the handout materials, which suggests that the participants did engage with the detail of the model.

2.3. Workshop Findings

This section first reports on the atmosphere at the workshop, using this to give a sense of how participants engaged with the model. Next, it addresses three specific questions key to the use of an ABM as an "interested amateur".

2.3.1. Atmosphere

In the first session, the participants engaged with the model in a lively way; discussion started quickly, with minimal prompting. The vibrant discussion continued throughout the session, with only minor prompting, and indeed continued beyond the allotted time. The session overran by approximately thirty

minutes. The buoyant and sustained discussion was an excellent sign of the participants' engagement with the model and its detail. They appeared interested in the model, and fears of difficulty with facilitation were quickly dispelled.

The discussions were good natured and friendly. Humour was used to deal with the organiser's position as a clear outsider. This made the discussion open, if a little informal. Arguably, the lack of formality was as positive as the setting (on a Western NGO campus), and the political and cultural sensitivity of some of the issues under discussion (e.g., land tenure, ethnicity) meant the discussion may have become difficult and constrained. Furthermore, the informality maximised the chance that the participants would be less guarded about their opinions, and the model could begin to become the "interested amateur" as envisaged. The organisers presented themselves clearly as a non-expert on SWC, hoping to get help from the participants. In this sense, continued inspiration was drawn from the concept of the "interested amateur": not only was the model playing this part, but so were they.

It is important to note that the participants seemed to like ABM in general. They did not show any apprehension or distaste for the methodology, which was likely unfamiliar to all. It was not required to go into a detailed discussion or defence of ABM in general. The participants' positive reaction to ABM supports the idea that ABM has an intuitive appeal. The participants also appeared to gain a strong grasp of what an ABM was and what it can do; though they asked many questions about the approach and model, they did not ask any (or make comments) that showed misunderstanding of the methodology. Again, this could easily not have been the case and was encouraging from the start.

The second session, aimed at gathering direct opinions on how the SWAP model could be used, had been planned in a similar way to the previous sessions, with the group breaking into smaller discussion groups before coming back together. However, as time had run over in the morning, the session was streamlined into one larger group discussion. This meant that the session seemed more formal, with the participants all facing the front as notes were taken on a flip-chart. This format appeared to inhibit the discussion; the participants were less engaged than when in smaller groups. The subject matter may have played a role in this, too; the topic was more hypothetical and removed from the participants' current work and experience. The topic was more explicitly selfish in terms of the organisers getting information from the participants without much potential benefit for the participants. This is likely to have also reduced the participants' engagement in discussions. Having the session after lunch also gave the session a sense of lethargy that was not present in the morning. Perhaps of most note was that this session, though focused on discussion about the model's use, did not make use of the model itself, as in the other session. This could provide the perfect example of how, without the model to aid discussion, the same group of participants were less engaged and discussion was less buoyant. Despite this change in atmosphere, the discussions did bring out some interesting points and were certainly of use.

2.3.2. Can An ABM Be Used as an "Interested Amateur" in the Context of SWC Policy?

The participants recognised the vast majority of the factors in the farmers' behaviour framework and recognised the forms of interaction under which the model assumes that farmers act. The participants agreed that all of the factors identified in the framework were relevant, but to varying degrees. They felt some were less important than others, because, as a generic set of factors, some were less applicable to their specific region or Ethiopia as a whole. The participants were critical of some parts of the

model, particularly the factors that they felt were inappropriate or less important, such as the use of the word "tribe" (one of the socio-economic factors identified in the DeGraaff framework) and the lack of a detailed biophysical representation.

There were some areas of discussion on which the participants did not come to a consensus. These included the prevalence of off-farm employment and/or activity and the prevalence of rented or short-term use of land. These differences became clear due to the explicit causation detailed in the model assumptions; they were challenged by some participants, but not others. It was the resulting debate on the direction of causation and the current status of these parameters (*i.e.*, how many farmers rent or own land) that brought out the differences in beliefs. There were also many contradictions in the discussion. For example, the same participant expressing one opinion early in the first session and, then, a mutually exclusive opinion later. This occurred because the presence of the model led participants to discuss a range of topics and to return and shift between topics in a way that they did not choose. Had the participants been in more control of the direction of discussion, without the model to lead them, it is possible that they could have easily avoided exposing these inconsistencies.

These differences and inconsistencies in opinion were clearly highlighted by the presence of the model in the participants' discussions. Whilst it is entirely possible that they may have reached these issues without the model, it is certain that the framework of agent behaviours, the granular detail it provides and participants' willingness to criticise the model led the participants directly to the main issues of contention. Having the model as the focus of discussion gave the participants an easy target at which to make their criticisms and assertions, in the full sight of others. In this sense, the model served as an excellent "interested amateur".

2.3.3. Can An ABM's Level of Detail Focus Discussion, whilst Still Keeping Concepts and Ideas Tractable?

The participants were quick to use the step-by-step and line-by-line nature of the agent rules as a guide for their discussion. This meant that they went through each step and its associated factors in a systematic manner. This certainly gave the discussion a level of detail that was valuable. At times, the discussion became very focussed on specific issues, and the participants made a lot of notes on each element of the model. The participants also went off on tangents on occasion. However, they appeared to never lose sight of the basic question of why farmers adopt SWC, returning to it without the need of prompting. Very little effort was required to keep the discussion on track, or on topic, as the model served as a natural chairperson. The main problem with the level of detail was that it meant that the session overran. This was mainly due to the depth to which the participants went through the model rules and assumptions. This highlighted the models' ability to force participants into a detailed discussion. Despite the overrun in time, all of the planned topics of discussion were covered. This was in part due to the model lending a clear structure to the discussions, allowing the participants to identify the next area of discussion easily. Once it was clear that time was overrunning, the participants appeared to check for the upcoming areas of discussion indicated by the model and insist that they wished to cover them also. In this sense, the model was successful in keeping the concepts and discussion tractable, if not concise.

2.3.4. Did Stakeholders See Value in the SWAP Model as An "Interested Amateur"?

The participants did recognise the value of the model as an "interested amateur", and agreed that it had shown differences in opinion amongst them and inconsistencies in their beliefs. Despite this, they were quick to suggest that the real value of using the model would be to those nearer the "bottom" of the policy process and working closely with farmers on a more regular basis. This appeared to be based on two beliefs. First, as the the model represents farmers' decision making, the participants appeared to see an intuitive appeal in using the model with farmers. Secondly, they seemed less keen on the idea that those "further up" the policy process needed to understand, or discuss, farmer behaviour in such detail; appearing to believe this was beneath them in some sense.

Of all the topics covered during the workshop, the only one for which almost completely negative views were expressed was the question of whether participants could use the SWAP model themselves. Beyond suggesting the model would be most useful to those nearer the "bottom" of the policy process, they were quick to suggest that it was not in their remit to "innovate" in the methods they use and that they would need to be instructed by their superiors to use such a tool as the SWAP model. It is not clear whether this is a genuine bureaucratic/administrative barrier to their use of such tools or whether this is a polite excuse, which avoids the need to be more critical of the potential to use the model as an "interested amateur".

3. Discussion

The SWAP model has shown us one example of how ABMs might be used as "interested amateurs" and begun to identify the barriers that may stand in the way of their use. This section will now attempt to outline more generally when and how this approach may be appropriate and consider some of the main challenges.

3.1. When to Use "Interested Amateurs"

There are two key issues that should help identify when using the "interested amateur" approach will be appropriate: firstly, when interaction, and the quality of interaction, between different policy stakeholders has been identified as problematic. This is a commonly-cited problem, in many policy domains, both in developing and developed countries. In land use policy, with a relatively high number of policy stakeholders, this is a particularly relevant issue. The approach has clear benefits in bringing together stakeholders and focussing discussions. However, this is true of other participatory approaches, namely companion modelling. Thus, secondly, what differentiates the "interested amateur" approach is that it allows the use of the model as an outsider, which can be an object for critique. The model becomes a "guess" at the behaviour of a system, which is easy to attack, both because it is an outsider (an amateur), but also because it is clearly not perfect or overly complex. Other participatory approaches may not allow for this type of attack or critique, as the simulation has been co-constructed, so that participants may be more hesitant to criticise it, because it is constructed by themselves and other stakeholders and is also less easily dismissed as an outsider. A model developed outside the immediate policy process is also more likely to contain thinking that is not being included in that process and so provoke criticism or new

discussion. It is also this outsider status that allows a model, which can be perceived as a sophisticated technical object, to be an "amateur". The main challenge in this case is that the benefits of stakeholders having ownership of the model are lost. This was reflected in the experience with the SWAP model; it was critiqued, but participants were hesitant about using it themselves (*i.e.*, longer term engagement was non-existent). This decision between using an approach that allows being an outsider and encouraging critique and that which allows ownership and encourages future use will be the second key starting point for any researcher or practitioner considering when to use the "interested amateur" approach.

3.2. How to Use "Interested Amateurs"

At this point, having suggested that researchers and practitioners may wish to use the "interested amateur" approach, it is helpful to make a few suggestions of how to go about doing this. Firstly, it is likely a sensible strategy to base the agent behaviour on a theory users may be familiar with or a middle-range theory with a strong intuitive appeal; for example, a theory that has been developed in the literature for the topic at hand or a theory that has been developed for the central type of decision the agents in a model are making. For the SWAP model, this meant using the DeGraaff *et al.* framework of farmers' decision to adopt SWC measures [21]. Alternatively, a middle-range type framework, such as the Consumat approach [27,28], could have been used, because it closely relates to the decision process that the agents in the ABM are going through and has an intuitive appeal (*i.e.*, it makes conceptual sense to beginners). Using theories like this will give the model an immediate and intuitive appeal, making the model not appear as a "black box". This will suit its use as an 'interested amateur" and make it easier to communicate to stakeholders. The alternative of using more probabilistic or rational utility maximisation type behaviour rules will be less useful in discussions, as they will appear further removed from reality and make discussions more technical.

A less common tactic in designing an ABM, but one that will improve the use of an "interested amateur" type model, is to include (and use in the decision rules) many parameters; indeed, more than one might typically hope to include in a relatively simple model. This goes against the KISS (keep it simple stupid) principle [29], which advocates keeping a model simple, with as few parameters as possible. This approach is intended to make a model more tractable when seeking to understand results, emergent phenomena or running experiments. However, in the context of using a model as an "interested amateur", it is likely to focus discussions on those few parameters included, at the expense of others. If it is our goal to draw out false assumptions and misunderstanding, this lack of breadth in the discussion will hamper the likelihood of success. Thus, it is suggested that those using an ABM as an "interested amateur" seek to include more parameters, so that the model has more detail on which to focus participants' discussions and, thus, enhances the granularity that makes an ABM such an excellent "interested amateur". This suggestion also reflects the focus on the design and assumptions of agent rules rather than model outputs, as seen in the SWAP example.

Finally, a key area of consideration should be how to communicate the model to stakeholders. In the example of the SWAP model, we saw how a presentation was combined with a self-led task and handouts. This allowed for a clear overview, with detail accessible when discussion and critique required. However, if the benefits of using an ABM are to be gained fully, we must constantly reconsider how our models

may be communicated, to capture their intuitive appeal, but also the level of detail in factors and their interaction. They must also be presented in a way that makes them amenable to critique. It is not our job as model developers to imbue our models with a sense of overt or undeniable credibility. Indeed, the more unimpressive a model appears, without actually being so poor that stakeholders dismiss it, the more likely it is to invite the critique that can be so valuable in its role as an "interested amateur". Giving users the chance to "play" with the model may also be a fruitful choice in some cases. Finally, one element that was not explored with the SWAP model, but that may be worthwhile, is considering how to communicate emergent phenomena and/or the results of the model more comprehensively and show how the micro-level assumptions of the model link to its macro-level results. Using various simple scenarios and comparing results is one potential avenue. Again, any approach used should be aimed at using the detail and intuitive appeal of the model, whilst keeping the model amenable to criticism.

By basing model development on existing academic literature, using many model parameters and considering carefully how the model can be positioned and presented to users, we will be able to maximise the chance that the model is accepted as a credible outsider and, thus, invite critique, but also contain thinking from outside the immediate policy process in which it is being used.

4. Conclusions

This paper has suggested that policy makers are experts in their policy area and that experts often have problems interacting effectively, owing to various pressures, which lead them to under-explain issues under discussion. It is suggested this is particularly true of land use policy in which there are many different stakeholders with a range of experiences and goals. The concept of the "interested amateur" has been used as inspiration for how ABMs might be used to help counter this problem. Dennett [5] suggests that "interested amateurs" can be included in experts' discussions to encourage the over-explaining of issues, with resulting benefits to the quality and effectiveness of discussions. This paper's main argument is that ABMs have the potential to play the role of "interested amateurs" in policy making processes. This is because of their unusual combination of characteristics; offering a high level of detail, intuitive appeal and explicit representation of causality. Furthermore, as models, they are more amenable to criticism resulting in debate than human facilitators.

This novel approach to the use of ABMs has been demonstrated with the example of the SWAP model of SWC. The use of the SWAP model at a workshop with SWC policy stakeholders showed how an ABM can be successful in generating and focussing discussion, inviting critique and allowing for the recognition of points of contention. However, the example also highlights the barriers to the use of a model over which policy stakeholders have no ownership.

Finally, some suggestions for when and how researchers and practitioners might wish to use an ABM as an "interested amateur" have been put forward. These highlight a key challenge for future research: to resolve the tension between the ownership and amenability to critique of a model. Both have benefits, but they appear mutually exclusive. Participatory modelling approaches that bridge this gap would be of great potential benefit to policy making processes.

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Conflicts of Interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; nor in the decision to publish the results.

References

1. Jäger, J. Current thinking on using scientific findings in environmental policy making. *Environ. Model. Assess.* **1998**, *3*, 143–153.
2. Matthies, M.; Giupponi, C.; Ostendorf, B. Environmental decision support systems: Current issues, methods and tools. *Environ. Model. Softw.* **2007**, *22*, 123–127.
3. Poch, M.; Comas, J.; Rodríguez-Roda, I.; Sànchez-Marrè, M.; Cortés, U. Designing and building real environmental decision support systems. *Environ. Model. Softw.* **2004**, *19*, 857–873.
4. Johnson, P.G. The SWAP Model: Policy and Theory Applications for Agent-Based Modelling of Soil and Water Conservation Adoption. Ph.D. Thesis, University of Surrey, Surrey, UK, 2014.
5. Dennett, D.C. *Intuition Pumps and Other Tools for Thinking*; W. W. Norton & Company: New York, NY, USA, 2013.
6. Ludi, E.; Belay, A.; Duncan, A.; Snyder, K.; Tucker, J.; Cullen, B.; Belissa, M.; Oljira, T.; Teferi, A.; Nigussie, Z.; *et al*. *Rhetoric versus Realities: A Diagnosis of Rainwater Management Development Processes in the Blue Nile Basin of Ethiopia*; CPWF Research for Development (R4D) Series 5: CGIAR Challenge Program on Water and Food (CPWF): Colombo, Sri Lanka, 2013.
7. Merrey, D.J.; Gebreselassie, T. *Promoting Improved Rainwater and Land Management in the Blue Nile (Abay) Basin of Ethiopia*; NBDC Technical Report 1; International Livestock Research Institute (ILRI): Nairobi, Kenya, 2011.
8. Smajgl, A. Challenging beliefs through multi-level participatory modelling in Indonesia. *Environ. Model. Softw.* **2010**, *25*, 1470–1476.
9. Voinov, A.; Bousquet, F. Modelling with stakeholders. *Environ. Model. Softw.* **2010**, *25*, 1268–1281.
10. Matthews, R.B.; Gilbert, N.G.; Roach, A.; Polhill, J.G.; Gotts, N.M. Agent-based land-use models: A review of applications. *Landsc. Ecol.* **2007**, *22*, 1447–1459.
11. Bousquet, E.F., Trébuil, G., Hardy, B., Eds. *Companion Modeling and Multi-Agent Systems for Integrated Natural Resource Management in Asia*; International Rice Research Institute: Los Baños, Philippines, 2005.
12. Étienne, M., Ed. *Companion Modelling: A Participatory Approach to Support Sustainable Development*; Springer: Enschede, The Netherlands, 2014.

13. Barreteau, O.; Antona, M.; D'Aquino, P.; Aubert, S.; Boissau, S.; Bousquet, F.; Dare, W.; Etienne, M.; Le Page, C.; Mathevet, R.; *et al.*. Our companion modelling approach. *J. Artif. Soc. Soc. Simul.* **2003**, *6*, 1.
14. Gurung, T.R.; Bousquet, F.; Trébuil, G. Companion modeling, conflict resolution, and institution building: Sharing irrigation water in the Lingmuteychu Watershed, Bhutan. *Ecol. Soc.* **2006**, *11*, 36.
15. Campo, P.; Bousquet, F.; Villanueva, T. Modelling with stakeholders within a development project. *Environ. Model. Softw.* **2010**, *25*, 1302–1321.
16. Campo, P.C.; Mendoza, G.A.; Guizol, P.; Villanueva, T.R.; Bousquet, F. Exploring management strategies for community-based forests using multi-agent systems: A case study in Palawan, Philippines. *J. Environ. Manag.* **2009**, *90*, 3607–3615.
17. Worrapimphong, K.; Gajaseni, N.; Le Page, C.; Bousquet, F. A companion modeling approach applied to fishery management. *Environ. Model. Softw.* **2010**, *25*, 1334–1344.
18. Grimm, V.; Berger, U.; Bastiansen, F.; Eliassen, S.; Ginot, V.; Giske, J.; Goss-Custard, J.; Grand, T.; Heinz, S.K.; Huse, G.; *et al*. A standard protocol for describing individual-based and agent-based models. *Ecol. Model.* **2006**, *198*, 115–126.
19. Grimm, V.; Berger, U.; De Angelis, D.L.; Polhill, J.G.; Giske, J.; Railsback, S.F. The ODD protocol: A review and first update. *Ecol. Model.* **2010**, *221*, 2760–2768.
20. Wilensky, U. *NetLogo*; Center for Connected Learning and Computer-Based Modeling, Northwestern University: Evanston, IL, USA, 1999. Available online: http://ccl.northwestern.edu/netlogo (accessed on 26 January 2015).
21. De Graaff, J.; Amsalu, A.; Bodnar, F.; Kessler, A.; Posthumus, H.; Tenge, A. Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Appl. Geogr.* **2008**, *28*, 271–280.
22. Wiegand, T.; Jeltsch, F.; Hanski, I.; Grimm, V. Using pattern-oriented modeling for revealing hidden information: A key for reconciling ecological theory and application. *Oikos* **2003**, *100*, 209–222.
23. Grimm, V.; Frank, K.; Jeltsch, F.; Brandl, R.; Uchmanski, J.; Wissel, C. Pattern-oriented modelling in population ecology. *Sci. Total Environ.* **1996**, *183*, 151–166.
24. Grimm, V.; Revilla, E.; Berger, U.; Jeltsch, F.; Mooij, W.M.; Railsback, S.F.; Thulke, H.H.; Weiner, J.; Wiegand, T.; De Angelis, D.L. Pattern-oriented modeling of agent-based complex systems: Lessons from ecology. *Science* **2005**, *310*, 987–91.
25. United Nations Environment Programme. *Global Environmental Outlook 4*; Progress Press Ltd: Valleta, Malta, 2007.
26. United Nations Environment Programme. *Global Environmental Outlook 5*; Progress Press Ltd: Valleta, Malta, 2011.
27. Jager, W.; Janssen, M.; Vlek, C. *Consumats in a Commons Dilemma: Testing the Behavioural Rules of Simulated Consumers*; COV Report No. 99-01; Center for Environmental and Traffic Psychology, University of Groningen: Groningen, The Netherlands, 1999.

28. Jager, W.; Janssen, M.A.; Vries, H.J.M.D.; Greef, J.D.; Vlek, C.A.J. Behaviour in commons dilemmas: Homo economicus and homo psychologicus in an ecological-economic model. *Ecol. Econ.* **2000**, *35*, 357–379.
29. Axelrod, R. *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration*; Princeton University Press: Princeton, NJ, USA, 1997.